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Elimination Effect of Cross Excitation Artifacts using the Changes of Flip Angle in 3.0 T MRI

Chang Gyu Kim*

Department of Radiological Science, Gimcheon University, GyungBuk 39528, Republic of Korea

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Magnetic resonance imaging (MRI) shows high contrast and resolution on the soft tissues and nervous tissues without radiation hazard, which is used as an essential diagnostic test in the radiology. Cross excitation means to show artifacts upon the signal loss from overlapped radio frequency (RF) in some anatomical locations during the image acquisition process with RF pulse. To lower cross excitation artifacts, their images were analyzed by the changes of flip angle, TR, and TE. Ingenia 3.0T CX MRI by Philips was used for image acquisition. Self-developed water phantom used for quality control of MRI was used. SNR values at 40 degree of flip angle were 1,354 ±7.12 and 214 ± 2.10; those at 70 degree were 1,375 ± 7.31 and 305 ± 2.12; and those at 90 degree were 1,413 ± 7.93 and 357 ± 2.33, for water and artifact, respectively. CNR values were 1,140 ± 7.01, 1,070 ± 7.18, and 1,056 ± 7.12 at 40, 70 and 90 degree of flip angle, respectively ($P < 0.05$). As flip angle was lowered more, artifact was decreased more. In case of 90 degree of flip angle, artifact was decreased more as TR was longer. These results are anticipated to be used as the fundamental data to acquire more valued medical images in terms of diagnostics with MRI to diagnose various diseases.

Keywords : cross talk, radio frequency, flip angle, artifact, phantom, SNR

1. Introduction

MRI is to express the proton of hydrogen in water and fat which are contained the most in the human body by processing their magnetic movement. MRI shows high contrast and resolution on the soft tissues and nervous tissues without radiation hazard, which is used as an essential diagnostic test in the radiology [1, 2]. However, it has the disadvantage to occur unnecessary artifacts in the diagnostic radiology such as environment of surrounding tissues, problems of device, error during the course imaging signal acquisition, incomplete authorization process of radio frequency (RF), and so on during the image acquisition process.

Cross talk effects are generated due to incomplete RF pulse authorization process causing artifact in MRI [3-5].

Unnecessary artifacts to images by cross talk effects can be classified as two cases. First, if the interval among selected sections is too close when multiple sections are scanned in the parallel anatomical areas, signal-to-noise (SNR) ratio is decreased over the whole selected areas to generate artifact, which is cross talk artifact. Second, if the selected two anatomical sections are maintained with the certain angle to be required and scanned simultaneously, black line image problems are appeared in the overlapped areas of authorized radio frequency as the number of overlapped slices, which is cross talk excitation artifact [6-10].

To decrease the artifacts generated by cross talk effects, 25 to 30 % of slice thickness between slices is placed or interleaving method is used in case of parallel scanning. Also, it is known that 3D techniques are more commonly used than 2 D techniques. Recently, 1.5T and 3.0T are commonly used for MRI to diagnose the human body. Compared to 1.5T, 3.0T has been known that scanning time is shorter with relatively good SNR and resolution [10-15].

This study was conducted to provide the useful clinical data upon measuring and analysis of artifact decreasing effects by the changes of flip angle, pulse sequence, TR, and TE, after generating cross talk excitation artifacts of water phantom, using 3.0T MRI device which has been widely used in the clinical practices.

*Corresponding author: Tel: +82-54-420-4046
Fax: +82-54-420-4462, e-mail: radkcg@hanmail.net

2. Cross Talk and Cross Excitation Effects

Physical mechanisms by overlapped authorization of RF are similar between cross talk and cross excitation, however, they should be separately treated to understand and eliminate the artifacts. Cross talk is occurred when 90-degree RF pulse is overlapped in the slice section of patient in case of parallel slice scanning. This phenomenon is occurred with partial overlapping between the first and second slices because 90-degree RF is not authorized ideally. In this phenomenon of 90-degree RF overlapping, solarization is generated upon receiving two 90-degree RF by a hydrogen proton and SNR lowering effect is developed in the acquired image [1, 5].

Cross excitation is a phenomenon that occurs when the subject anatomical area has the positional angle during the course to acquire the images of consecutive slices from the human body. In the course to acquire the images with RF pulse, RF is overlapped in some anatomical locations losing the signal and appearing the artifacts (Fig. 1, 2).

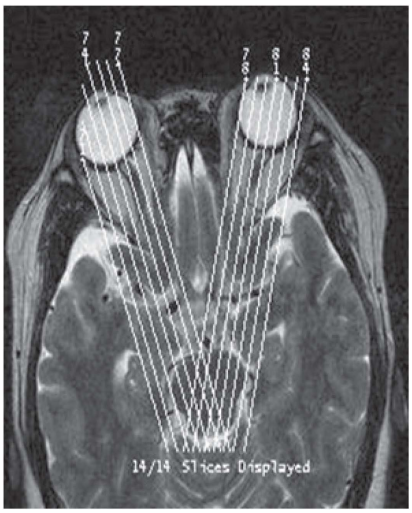


Fig. 1. Cross excitation RF authorization.

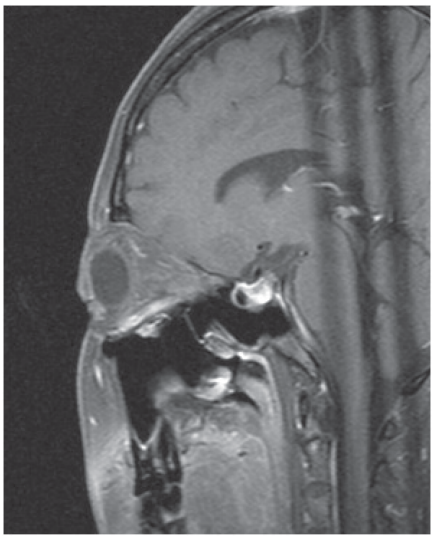


Fig. 2. Cross excitation artifact.

3. Study Subjects and Methods

3.1. Materials and tools

3.0T MRI device used was Ingenia 3.0T CX by Philips in the study. Phantom to acquire the images was self-developed water phantom used for quality control of MRI (Fig. 3). With respect to the scanning conditions, pulse sequence was used with turbo spin echo (TSE); field of view 220 × 220 mm; echo train length (ETL) 16; flip angles of 40, 70, 90, and 180 degree; time repetition (TR) 1092 ms; time echo (TE) 100 ms; and Matrix/NEX of 552 × 549/NEX, as seen in (Table 1).

3.2. MRI assessments

To confirm the clinical practicality of acquired images, SNR was measured. In region of interest (ROI) 28 × 28mm, mean values were measured to analyze the signal lowering. SNR was calculated by the formula with signal intensity (SI) of ROI divide by background SI (1).

$$\mathrm{SNR} = \frac{\mathrm{SI}}{\mathrm{Background\ SI}} \quad (1)$$

Fig. 3. (Color online) MRI device.

Table 1. Magnetic resonance imaging scanning parameter.

Parameter	
FOV	220 × 200 mm
ET	16
FA	40, 70, 90, 180°
TR	1092 ms
TE	100 ms
Matrix/NEX	552 × 549/NEX
Pulse sequence	TSE

Contrast Noise Ratio (CNR) was calculated by the formula that water SI subtracted noise SI and then divide by background SI (2).

$$\text{CNR} = \frac{\text{Waer SI} - \text{Noise SI}}{\text{Background SI}} \quad (2)$$

3.3. Statistical analysis

For data analysis, SPSSWIN (Ver 21.0) statistical program was used. T-test and ANOVA were performed for the significance tests on the mean values of measured exposure levels in the control and test groups. Significance level was $P < 0.05$ for all the statistical values.

4. Results and Discussion

4.1. Image analysis by the changes of flip angle

Artifacts occurred in MRI due to the problems of images are all the phenomena resulting in the unnecessary images as the final ones because of the problems of patients, surrounding environment, and device itself until the final image acquisition required for the diagnosis using magnetic resonance phenomenon. These artifacts can be eliminated or minimized upon understanding the causes and applying the countermeasures in the course of image acquisition.

The cause of cross excitation artifacts is overlapped authorization of RF which echoed hydrogen proton in the tissue to receive the signal of the subject tissue. Overlapped authorization of RF results in lowering signal. To eliminate this signal lowering, 25 to 30 % of slice thickness between slices is placed or interleaving method is used not to overlap the selected slices.

In this study, the changes of cross excitation artifacts were analyzed by the changes of flip angle. With respect to MRI analysis, pulse sequence was used with turbo spin echo (TSE); field of view 220 × 220 mm; echo train length (ETL) 16; flip angles of 40, 70, 90, and 180 degree; time repetition (TR) 1092ms; time echo (TE) 100 ms; and Matrix/NEX of 552×549/NEX.

Table 2. SNR values by the changes of flip angle in the TSE T2 images.

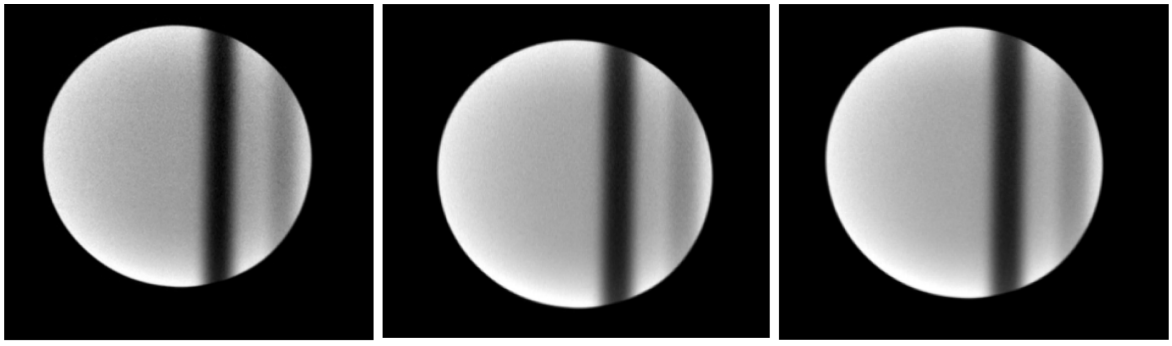
Flip Angle	40	70	90
Normal	1,354 ± 7.12	1,375 ± 7.31	1,413 ± 7.93
artifacts	214 ± 2.10	305 ± 2.12	357 ± 2.33
p-value	< 0.05	< 0.05	< 0.05

Table 3. CNR values by the changes of flip angle in the TSE T2 images.

Flip Angle	40	70	90
CNR	1,140 ± 7.02	1,070 ± 7.18	1,056 ± 7.12

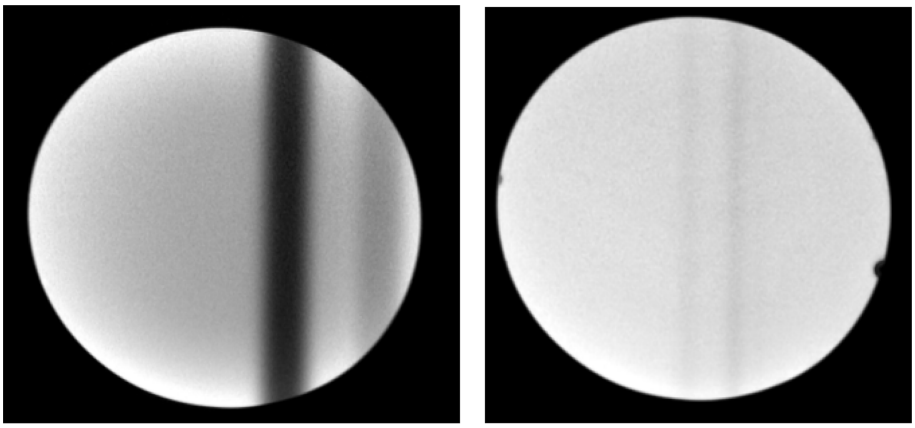
The results of cross excitation artifact images by the changes of flip angle are as seen in Fig. 4. SNR values at 40 degree of flip angle were 1,354 ± 7.12 and 214 ± 2.10; those at 70 degree were 1,375 ± 7.31 and 305 ± 2.12; and those at 90 degree were 1,413 ± 7.93 and 357 ± 2.33, for water and artifact, respectively. CNR values were 1,140 ± 7.01, 1,070 ± 7.18, and 1,056 ± 7.12 at 40, 70 and 90 degree of flip angle, respectively. These results implicate the decrease of cross excitation artifacts in case of image acquisition with low flip angle (Table 2, 3).

When MRI is acquired from the human body, RF pulse is added to amplify the signal. The way to add this RF pulse is pulse sequence. MR parameters such as flip angle, TR, TE and so on will vary depending on the pulse sequence. Cross excitation artifacts were decreased in the image acquired using Turbo Spin Echo with 90 degree of flip angle and the image of Gradient Echo with 28 degree of flip angle (Fig. 5). These results demonstrated decreasing of cross excitation artifacts in case with low flip angle. In the clinical practices to examine the regions that



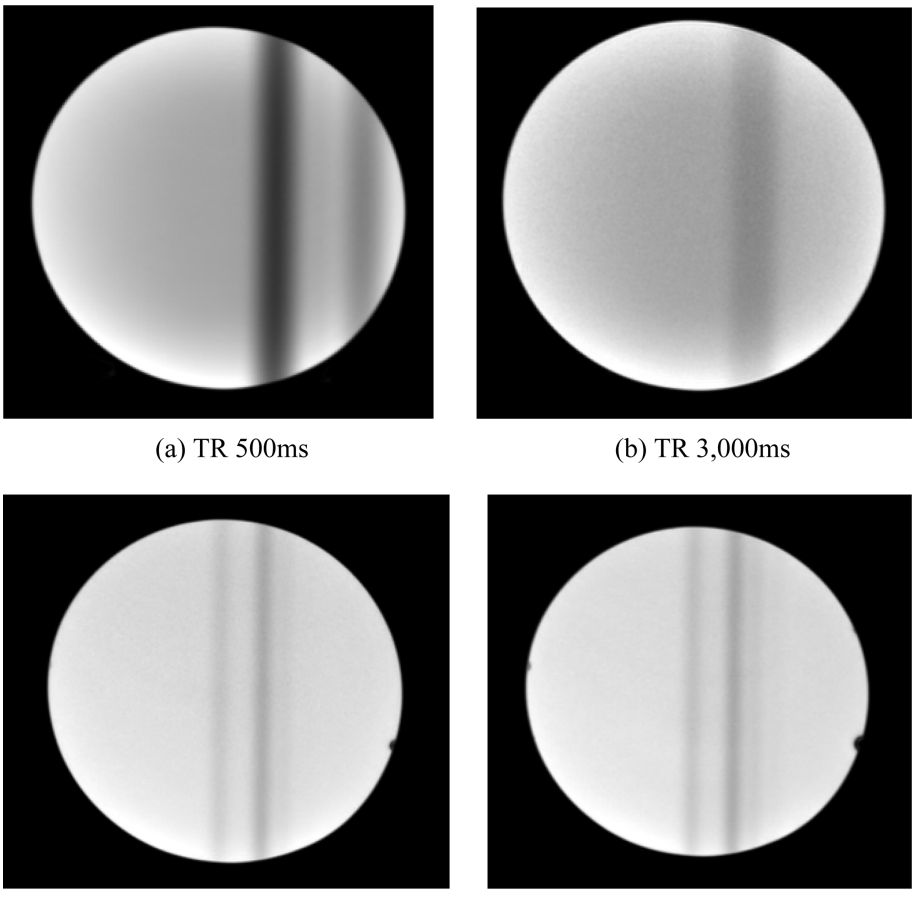
(a) 40 degree (b) 70 degree (c) 90 degree

Fig. 4. (a) 40 degree, (b) 70 degree and (c) 90 degree MRIs by the changes of flip angle.



(a) 90 degree TSE (b) 28 degree GE

Fig. 5. (a) 90 degree TSE, (b) 28 degree GE MRIs by the changes of pulse sequence and flip angle.



(a) TR 500ms (b) TR 3,000ms

(c) TE 13ms (d) TE 80ms

Fig. 6. (a) TR 500 ms, (b) TR 3,000 ms, (c) TE 13 ms, b) TE 80 ms Images by the changes of TR, TE at 90 degree of flip angle.

may occur cross excitation artifacts, the test should be performed by controlling MR parameters and so on considering these factors.

4.2. Image assessment results by the changes of TR and TE

The results of cross excitation artifacts by the changes of TR are as seen in (Fig. 6(a), (b)). As TR was extended

using 90-degree flip angle, decreased artifacts were found. These results implicate that artifacts can be decreased using the examination technique to extend TR in lumbar spinal test, thoracic spinal test, abdominal test, and so on with MRI, which is anticipated to take the optimum images in the diagnosis. The results of cross excitation artifacts by the changes of TE are as seen in (Fig. 6(c), (d)). These results demonstrated that TE did not affect the artifacts in MRI. This implicates it is necessary to extend TR to acquire the medical images with excellent diagnostic values in MRI to diagnose the diseases.

5. Conclusions

Cross excitation generates the artifacts due to the overlapped authorization phenomenon of RF which echoes the hydrogen proton in the tissues to acquire the signal in the subject tissues. To decrease cross excitation artifacts, the images of artifacts were analyzed by the changes of flip angle, TR and TE. SNR values at 40 degree of flip angle were $1{,}354 \pm 7.12$ and 214 ± 2.10; those at 70 degree were $1{,}375 \pm 7.31$ and 305 ± 2.12; and those at 90 degree were $1{,}413 \pm 7.93$ and 357 ± 2.33, for water and artifact, respectively. CNR values were shown as $1{,}140 \pm 7.01$, $1{,}070 \pm 7.18$, and $1{,}056 \pm 7.12$ at 40, 70 and 90 degree of flip angle, respectively ($P < 0.05$). As flip angle was lowered more, artifact was decreased more. In case of 90 degree of flip angle, artifact was decreased more as TR was longer. These data are anticipated to be used as the fundamental data to acquire the medical images with excellent diagnostic values in MRI to diagnose a variety of diseases.

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References

[1] A. S. Gaspar, R. G. Nunes, G. Ferrazzi, E. J. Hughes, J. Hutter, S. J. Malik, L. McCabe, K. P. Baruteau, M. A. Rutherford, J. V. Hajnal, and A. N. Price, Magn. Reson. Med. **81**, 477 (2019).
[2] S. Brandão, L. Nogueira, E. Matos, R. G. Nunes, H. A. Ferreira, J. Loureiro, and I. Ramos, Radiol. Med. **120**, 705 (2015).
[3] K. H. Nam, K. M. Lee, J. H. Kim, S. K. Park, Y. D. Kim, and D. C. Kweon, J. Magn. **23**, 364 (2018).
[4] Y. S. Han, S. C. Lee, D. Y. Lee, J. W. Choi, J. W. Lee, and D. C. Kweon, J. Magn. **21**, 115 (2016).
[5] J. W. Kim, W. S. Park, H. S. Kim, S. C. Kim, Y. H. Kang, T. K. Kim, D. K. Han, and Y. C. Heo, J. Magn. **23**, 570 (2018).
[6] W. J. Shin, J. Korean Soc. Radiol. **10**, 629 (2016).
[7] S. Y. Lee, J. Han, and D. C. Kweon, J. Magn. **24**, 303 (2019).
[8] D. K. Han, K. Kim, and Y. J. Lee, J. Magn. **24**, 223 (2019).
[9] European Society of Radiology, Insights Imaging **6**, 141 (2015).
[10] J. H. Thrall, Radiology **279**, 660 (2016).
[11] M. Mascalchi, G. Belli, M. Zappa, G. Picozzi, M. Falchini, R. D. Nave, G. Allescia, A. Masi, A. L. Pegna, N. Villari, and E. Paci, AJR **187**, 421 (2006).
[12] M. S. Cho, J. H. Cho, Y. M. Chang, Y. H. Cho, S. K. Zeon, K. R. Dong, W. K. Chung, H. K. Lee, H. J. Kim, J. Y. Bae, J. O. Ahn, and S. J. Lee, J. Magn. **16**, 350 (2011).
[13] Y. Lee, M. H. Choi, H. J. Goh, and D. K. Han, J. Magn. **21**, 281 (2016).
[14] W. J. Choi and D. H. Kim, J. Korean Soc. Radiol. **13**, 581 (2019).
[15] Y. S. Han and J. Y. Kim, J. Korean Magn. Soc. **28**, 192 (2018).